



# Ventilation for Basement Car Parks

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## Introduction

Basement car parks are proliferating in the urban habitat. What with side open spaces being enlarged to meet fire safety norms, surface parking is becoming a thing of the past. With ever increasing population growth and limited space, town planners are taking recourse to vertical expansion resulting in high rise buildings with many habitable floors to accommodate as many tenements as possible within a limited footprint.

Added to this is the phenomenal growth of car population in Indian cities. Multiple cars per family are becoming the norm rather than the exception.

Public parking used to be in open spaces, but this could in no way keep pace with the growing car population in cities. Municipal corporations have devised a method where, if a developer incorporates certain amount of public car parking in a building, he is incentivized by grant of additional construction permission for residential or commercial use.

With ever increasing demand for urban housing as well as commercial spaces, the developer is left with no option but to provide multilevel car parks either above or below ground level. Again, building height restrictions imposed primarily on account of fire fighting considerations go in favour of parking

basements below ground rather than parking decks above. This is how basement car parks have become a standard feature in high rise buildings.

## Ventilation and Smoke Management

Fouling of the car park environment happens when a car stops, starts and traverses the park. The purpose of a ventilation system is to remove contaminated air and allow outside air as replacement, so that the net concentration of the foul gases is within acceptable limits. Acceptable limits govern one hour to eight hours exposure of humans. The analysis below is to establish such an acceptable environment.

*Fire mode ventilation*, on the other hand, has the following objectives:

- i) Maintain smoke level at 2 to 2.5m so as to enable easy evacuation and to facilitate fire fighters to reach the fire.
- ii) Maintain obscuration levels within limits so that exit and other signage are visible.

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## About the Author

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This will involve:

- i) Establishing design fire size.
- ii) Acceptable smoke layer depth.
- iii) Computation of smoke volume and temperature.
- iv) Minimum number of extract and intake points.

Such a study is not within the scope of this article.

When basements are used as habitable spaces, ANSI/ASHRAE Ventilation Standard 62.1 or equivalent may be followed. It may be noted that Standard 62.1 does not distinguish between spaces above and below ground level.

For spaces below ground that are normally occupied, such as Back of House areas in a hotel, it is advisable to provide air conditioning in which case comfort standards as per ASHRAE 55.1 or equivalent will prevail.

For equipment rooms located in the basement, such as air conditioning plant rooms or PHE/ fire fighting pump rooms, the circulating air requirement will depend on heat generation by the operating equipment and temperature rise that could be permitted as specified by equipment manufacturers.

In this article, we will look only at spaces below ground, which are used for parking of vehicles. Further, for simplicity, the discussion is limited to parking basements which are fully enclosed.

## Ventilation Requirements for Basement Parking Spaces

Enclosed parking area in the basement requires mechanical ventilation. The major areas of concern in vehicular emissions are carbon monoxide, oil and petrol fumes and NOx from diesel vehicles. Of the three, carbon monoxide is the most hazardous component. It is colourless, odourless and lighter than air. It gives no warning of its presence and when inhaled, it is absorbed by hemoglobin in the blood and destroys the blood's ability to transport oxygen to body cells. Even dilute concentrations of CO in air result in headaches, nausea and vertigo.

Oil and petrol fumes also cause nausea and headaches and are potential fire hazards. Nitrogen oxides resulting from diesel burning in passenger cars also produce similar results.

The ventilation rate required to dilute CO to acceptable levels is, however, satisfactory to control other contaminants



An axial flow fan at basement periphery

as well, especially since passenger cars with diesel vehicles may not constitute more than 20% of total vehicles in the parking lot. Design ventilation rate for a basement parking lot can be determined based on the following:

1. Number of cars in the parking lot and number in operation during peak hour.
2. Emission rate of a typical car.
3. Average travel time of car within the parking lot.
4. Acceptable level of CO concentration.

The number of cars in a parking lot can vary as per the configuration and planning of drive- ways etc., and can vary from 30 sq.m. to 50 sq.m. per car. Cars simultaneously in operation vary from 3 to 5% for a residential apartment or commercial building. This can however go as high as 15 to 20% for a cricket stadium or multiplex cinema.

With the stringent environmental regulations, emission rates of cars have been steadily reducing. On entering a parking lot, the car travels slowly and in low gear and the engine runs hot. While exiting, the car is again in slow speed and low gear but the engine runs cold and the emissions tend to be higher. Emission data, especially in parking garages, published by the Environment Protection Agency of the USA (EPA) are shown in Table 1.

Table 1: Emission data in parking garages (g/min.)

Engine running mode	Hot		Cold	
	1991	1996	1991	1996
*Year	1991	1996	1991	1996
Summer 32°C	2.54	1.89	4.27	3.66
Winter 0°C	3.61	3.38	20.74	18.96

\*Latest years for which emission data is available in ASHRAE Applications on the website

The length of time a car is idling or travelling within the parking facility is a function of its size and layout, and the operating time may vary from 60 seconds to 600 seconds. However, 180 seconds could be taken as the average. (This should be adjusted to suit the specific configuration and may be validated by actual observation in the facility).

Carbon monoxide concentration permitted by various codes is given in Table 2.

Table 2: Carbon monoxide concentration permitted by various codes

	Average mg/ m <sup>3</sup>	Peak mg/ m <sup>3</sup>
US EPA	40 (upto 1 hour)	NA
European Standards	40	230
British Building Regulation	32.5 (for 8 hour period)	97.5 (not exceeding 15 minutes)
ASHRAE	29 (for 8 hour exposure)	130
India NBC 2005	29	137

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To determine the required air changes per hour (ACH) to maintain a safe level of CO concentration within the parking facility, the following method of calculation can be followed:

Let us consider a parking garage in the second basement (2 levels below ground) of 5,000 sq.m. area and a height of 3m.

Table 3: Determination of required air changes

S. No.	Parameter	Unit	Value
1.	Area of parking lot	sq.m.	5000
2.	Height	m	3
3.	Volume	m <sup>3</sup>	15000
4.	Parking concentration	m <sup>3</sup> /car	40
5.	Number of cars	(1) ÷ (4)	125
6.	Cars in operation in peak hour	No.	3% at one time i.e. 3% in 3 minutes, or 60% per hour = 75 cars
7.	Average CO emission at 32°C (see Table 1)	g/min	$\frac{1.89 + 3.66}{2} = 2.775$
		g/hour	2.775 x 60 = 167
8.	Average travel time	Seconds	180
		Minutes	3
9.	Peak CO generation	g/h.m <sup>2</sup>	$\frac{75 \times 167}{5000} = 2.505$
10.	*Normalised peak CO generation using reference value of 26.7 g/h.m <sup>2</sup>		$\frac{100 \times 2.505}{26.7} = 9.38$
11.	Design CO max (see Table 2 – India NBC 2005)	ppm	25
		mg/m <sup>3</sup>	29
12.	*Quantity of exhaust air	m <sup>3</sup> /s.m <sup>2</sup>	$0.692 \times 10^{-6} \times 9.38 \times 180$ seconds = 0.001168
		m <sup>3</sup> /h.m <sup>2</sup>	0.001168 x 3600 = 4.2048
		ACH	4.2048 / 3m = 1.4

\*ASHRAE Applications 2011

Since vehicle emissions have been brought down through research and studies, the ventilation rate required to maintain carbon monoxide within permissible limits can be lower than applicable codes and standards, which are given below.

### International Codes for Ventilation of Parking Spaces

- ANSI/ASHRAE Standard 62.1 – 2007 requires a minimum exhaust rate of 3.7 l/s.m<sup>2</sup>, which is equal to 4.44 air changes for the above example.
- NFPA 88A recommends a minimum of 0.005 m<sup>3</sup>/second per sq.m., which is 5 air changes.
- British Building Regulations 2010 (F-Ventilation) require a

mechanical ventilation system capable of 6 air changes per hour for basement car parks with an additional provision for a local ventilation rate of at least 10 air changes per hour for exits and ramps.

### Indian Codes

NBC 2005 (Section 6.5.4.1) recommends ventilation rate of 30 to 60m<sup>3</sup>/h per m<sup>2</sup>. For a 3 meter high parking lot, this works out to 10 to 20 air changes per hour. Local authorities such as Municipal Corporation of Greater Mumbai stipulate 15 air changes per hour for basements.

### Control of Ventilation Based on CO Level

If permitted by local codes, the ventilation air flow rate can be varied according to CO levels to conserve energy. This can be achieved easily with multiple fans either with dual speed motors or motors connected to variable frequency drives (VFDs). In multilevel basements as well as in large single level structures, independent fan systems with individual control are required. This is to take care of fire compartmentation requirements, which specify that a single compartment cannot exceed 750 sq.m. in area for a non sprinkled building and 1125 sq.m. (750 + 50%) for a sprinkled building.



A basement exhaust outlet at ground level

Significant energy savings are possible with demand control ventilation (DCV), which varies the fan speed to regulate CO levels below the stipulated 29 mg/m<sup>3</sup>. This means that even if larger fans are installed to meet code requirements, power consumption will not necessarily increase as long as demand control ventilation is used.

### Minimum Separation Distance between Intake and Exhaust

In large basements that are compartmentalized, due care must be taken to separate the air intake from the contaminated air exhaust point. ANSI/ASHRAE 62.1-2007 stipulates a minimum distance of 5m between outside air intake and the potential outdoor contaminant source, which will be the location of the exhaust in respect of the parking garage and drive-in-queue.

### System Configuration

Basement ventilation systems will generally be a combination of supply and exhaust. While 40% of the exhaust air is permitted by natural aspiration through ramps and other openings in respect of

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the basement closest to ground, for all lower levels 100% of the exhaust air has to be compensated through forced air supply.

It is important to avoid short cycling of supply air and to provide efficient, adequate air flow throughout the parking facility. The design should provide for stratification of engine exhaust where stationary cars are kept idling, such as near a ticket booth or an exit ramp.

### **Design Strategy**

One of the first international class buildings in India was the Air India Building at Nariman Point, Mumbai that was built in the 1960s with enclosed parking garages in the basements. The architects were from Chicago and the building followed Chicago City Code which required 18.0 m<sup>3</sup>/hour.m<sup>2</sup> with 1/3 extraction at low level and 2/3 at high level. Exhaust ducting was put in place and the basements were designed with sufficient height with the ducting in position.

Most of the buildings constructed later followed the same practice. Even today there are no prescriptive requirements for basement ventilation of enclosed parking garages, but basement heights are steadily coming down (in order to reduce construction costs) and 3 or 4 basements are becoming the norm, with the result that ducting with distributed extraction is difficult to accommodate.

Height restrictions in parking basements and the consequent difficulty in accommodating ducted exhaust systems have made impulse ventilation by means of high thrust 'jet fans' quite popular. These fans produce a high velocity jet of air, which in turn moves a larger mass of surrounding air through a process known as entrainment. Axial flow jet fans have been successfully used for road tunnel ventilation for some time. However, some authorities do not accept them for ventilation or smoke exhaust in parking basements.

In a ventilation system operating on impulse ventilation principle, the number and locations of individual fans with respect to each other and with respect to the supply point and ultimate exhaust point, as brought out by a CFD analysis, are most important. While these fans provide for movement of smoke (in a fire situation) that is buoyant and rises to the top, they have little effect on low level discharge of carbon monoxide and other contaminants from

automobile exhaust. At lower levels, air will be drifting at low velocities leaving several pockets of contaminated air.

Further, since jet fans along with their mounting arrangement require a depth of 400 to 450 mm from the slab soffit level, the normal tendency is to locate them between beams or even at 'convenient locations' where they do not obstruct vehicle movement and parking. This defeats the whole purpose of CFD analysis for determining fan locations.

However, lower system costs and adaptability in low height basements have made them a favorite of architects and developers. A convincing CFD analysis at design stage and testing of the system for CO levels after installation should be pre-requisites for recommending a jet fan system.

### **Conclusion**

In addition to the normal ventilation requirements to keep pollutants within acceptable limits, there is a need for the smoke extraction systems to achieve the specified number of air changes (as low as 6 under *Uniform Plumbing Code*, USA and as high as 30 under *National Building Code 2005*, India). This, however, can be non-ducted drift ventilation, keeping in mind fire compartmentation requirements. A smoke extract system is required to operate only during fire mode but can be made to complement the car park exhaust as a flushing system through periodic operation, say every 4 hours or so. The two systems together may present a more effective design strategy. ❖



*A jet fan*